Augmenting Tactile 3D Data Exploration With Pressure Sensing

Xiyao Wang, Lonni Besançon, Mehdi Ammi, Tobias Isenberg

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Xiyao Wang*
Inria, Université Paris-Saclay

Lonni Besançon*
Inria, Université Paris-Saclay

Mehdi Ammi†
CNRS

Tobias Isenberg*
Inria, Université Paris-Saclay

Abstract

We present a pressure-augmented tactile interaction technique to improve 3D object/view manipulation tasks on mobile devices. Existing tactile techniques for mobile data exploration either make use of up to four fingers to control all the needed degrees of freedom (DOF) for 3D manipulation or simultaneously adjust multiple DOF together to reduce the number of fingers needed for interaction. Yet the small display size of mobile devices limits the number of fingers that should simultaneously be used. Controlling each DOF for 3D data exploration separately, however, gives users more control. We address this contradiction by combining tactile and pressure input. We thus use pressure to intuitively switch between different tactile interaction modes. In this extended abstract we describe our interaction design as well as our rationale for the input mappings.

Index Terms: Human-centered computing—Visualization—Visualization application domains—Scientific visualization

1 Introduction

We present the design of an interaction technique that adds pressure-based input sensing to the classical tactile sensing for 3D interaction. This interaction technique aims at better supporting 3D data exploration for scientific visualization. Pressure (also called isometric force) is a continuous form of input that is increasingly used in HCI systems (e. g., [3, 9]). In our work we use of pressure input to augment tactile interaction for the specific use of 3D manipulations of objects or the navigation in 3D datasets. 3D manipulations/navigation requires up to 7 DOF: 3 DOF for translations, 3 DOF for rotations, and 1 DOF for uniform scaling. On the other hand, tactile input facilitates the manipulation of 2 DOF (1 per axis on the screen) per finger. It is clear that a single finger cannot provide enough DOF for 3D navigation/manipulations. However, tactile interaction offers the possibility to use several fingers together to increase the input DOF. Thus, techniques for 3D manipulations have been developed that make use of up to four fingers (see eg, [6, 7, 16]).

An increase of the number of fingers used for interacting, however, also increases the occlusion problem that is inherent to tactile interaction. Even though occlusion may be a small problem in some specific setups (i. e., large displays, tabletops, etc.), it is an important issue for mobile devices whose screens tend to be relatively small. Consequently, it seems that the predominant tactile interaction technique for 3D interaction on mobile devices is a technique which makes use of only two fingers [2]: one finger for an ARCBALL rotation around the *x*-/*y*-axes and two fingers for *x*-/*y*-translations, rotations around the *z*-axis, and zooming/translation along the *z*-axis. Even though this technique is frequently employed, there is no clear interaction standard for 3D-manipulation applications on mobile devices. Recent work [2] also showed the 1/2-finger mapping to be confusing because it integrates too many DOF simultaneously.

*e-mail: {xiyao.wang | lonni.besancon | tobias.isenberg}@inria.fr
†e-mail: mehdi.ammi@limsi.fr

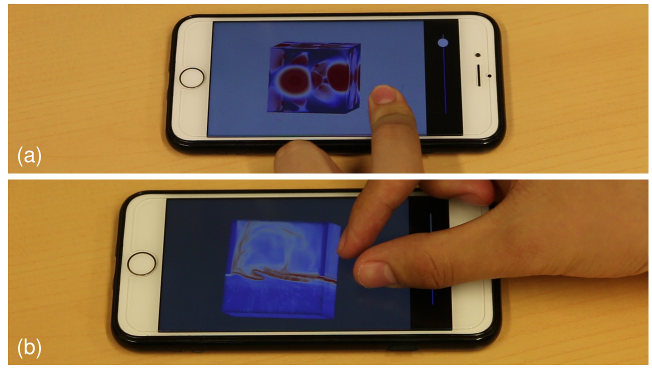

Figure 1: Data exploration with (a) 1-finger and (b) 2-finger control.

2 Context and Related Work

Direct-touch interaction (i. e., using tactile input captured on the display screen) has been proven to be efficient for both 2D and 3D manipulation tasks [11, 13]. Techniques such as RST (rotation scale translation) [8] have widely been used in a variety of system for application domains such as scientific visualization. Hancock et al. [6], e. g., extended the existing RST into a 3D version and provided several mappings with one-, two-, or three-touch input to support 3D interaction. While their results proved that tree-touch input has better completion time and user preference, such a technique can hardly be implemented on a mobile device which presents a very small display and interaction space. Other techniques have also been developed that use either three fingers (e. g., Sticky Tools [7]), four fingers (e. g., [16]), or specific widgets (e. g., [5, 18]). Again, due to the limited screen size on mobile devices most of these techniques would not be usable without sacrificing data viewing (i. e., occlusion) or usability. We thus propose to limit the number of fingers needed to two, while still separating all DOF for a better manipulation [14].

To achieve this goal we rely on pressure input. Hancock et al. [7] proposed to use pressure input to augment tactile interaction but did not implement their idea or propose any mapping. Later, Heo et al. [9] used out-of-screen pressure input to distinguish between several gestures such as drag or slide. Similarly, Besançon et al. [3] used back-of-device pressure sensors to control gain factor manipulation, while Pelurson et al. [15] installed a pressure sensor on the front bezel of the input device to augment navigation of large 1D data. In contrast to these approaches, we employ on-screen pressure sensing such as used, e. g., by Brewster et al. [4] for text entry.

3 Interaction technique and implementation

We propose to augment tactile interaction with pressure input to offer 6 DOF control for 3D interaction. Specifically, we use the pressure input to design quasi-postural [12] moding: based on the pressure at the start of an interaction we do not manipulate the 3D data but rather switch between DOF to be affected by tactile input. Moreover, we use pressure only as a binary form of input (difference of soft and hard touch) because maintaining a constant pressure level has been shown to be a difficult task [9].

To separate the DOF we map all manipulations related to the *x*-/*y*-axes to a single-finger input, while manipulations related to the *z*-axis

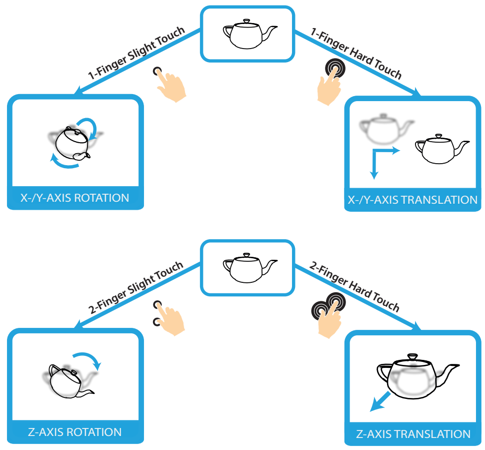

Figure 2: Diagram of the separation of DOF according to the number of fingers interacting and the pressure applied

are done with two fingers. If a single-finger interaction starts with low pressure (e. g., Fig. 1(a)), its motion is mapped to ARCBALL rotation. An initial hard touch leads to a x-/y-translation. If two fingers are present with slight touch (e. g., Fig. 1(b)), we initiate a either a uniform zoom or a z-translation based on the application [7]. If a second finger is put down after the first initiated a hard touch, however, we initiate a rotation around the z-axis. The pressure is only important at the start of a manipulation and is used in a spring-loaded fashion [17]. The pressure threshold can be adjusted by the user and the transition from soft to a hard touch is signaled to the user with haptic feedback [10] (device vibration). This design allows us to provide access to all 6 DOF individually (see Fig. 2), following recommendations by several researchers [14, 18]. Our interaction design also limits the number of fingers on screen to a maximum of two to obstruct the view of the dataset as little as possible.

We implemented our interaction technique on an iPhone 6S (4.7" screen diagonal, 750×1334 pixels, 326 ppi, iOS 10.3.2). We capture input events (tactile and pressure) with Swift 3, and render with OpenGL ES 3.0. We also support scientific datasets (*.vtk or *.vti) that we first read using the VTK 6.3 framework and then render using our own implementation.

4 Discussion and Future Work

With our technique we support 3D data exploration for scientific visualization. While such exploration usually relies on specific setups such as workstations, large displays, or VR, our goal is to extend this spectrum to mobile devices to give researchers more choice in selecting a suitable data exploration environment as well as make it easier for them to transition between different settings. We can thus compare it to existing tactile input techniques for 3D data manipulation that are used on large devices [11]. Compared to 3D-RST [16] and Sticky Tools [7], for example, it separates out the individual DOF and works reliably with only two-finger input. In contrast to tBox control [5], we do not need to draw a graphical widget on top of the data display. Compared to FI3D [18], finally, we no longer need a frame widget to distinguish the controlled DOF which would take valuable screen space.

Dedicated pressure sensing is currently only available on a few smartphones. On other mobile devices, however, we could make use of pseudo-pressure sensing which is based on the contact area between the finger and the screen. It uses the fact that a higher pressure leads to an increased contact area and some applications have used it successfully (e. g., [1]). While this type of sensing is less precise, it is likely to be sufficient for our purpose because we only require a binary decision between a strong and a weak pressure.

Future work includes, in particular, a user study to evaluate our interaction design compared to existing tactile 3D navigation techniques. In particular, we want to test whether the mobile device's size has an impact on people's navigation performance. Furthermore, we also have to investigate the integration of our interaction design into more complex data exploration solutions as any practical tool will need to include, beyond data navigation, several additional tools such as selection, seeding, cutting plane manipulation, etc. Finally, we believe that the used gain-factor (i. e., C/D ratio) value could impact the results: a high gain factor value combined with an integrated DOF interaction technique may increase the confusion or frustration of users. In contrast, a small gain factor value would probably mean that simultaneous DOF control would be less problematic.

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